

An Accurate Method to Determine Electric Motor Efficiency While the Motor is in Operation

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Outline

- Background
- New method for determining electric motor efficiency
- Implementation
- Accuracy vs lab tests
- Conclusions

Background

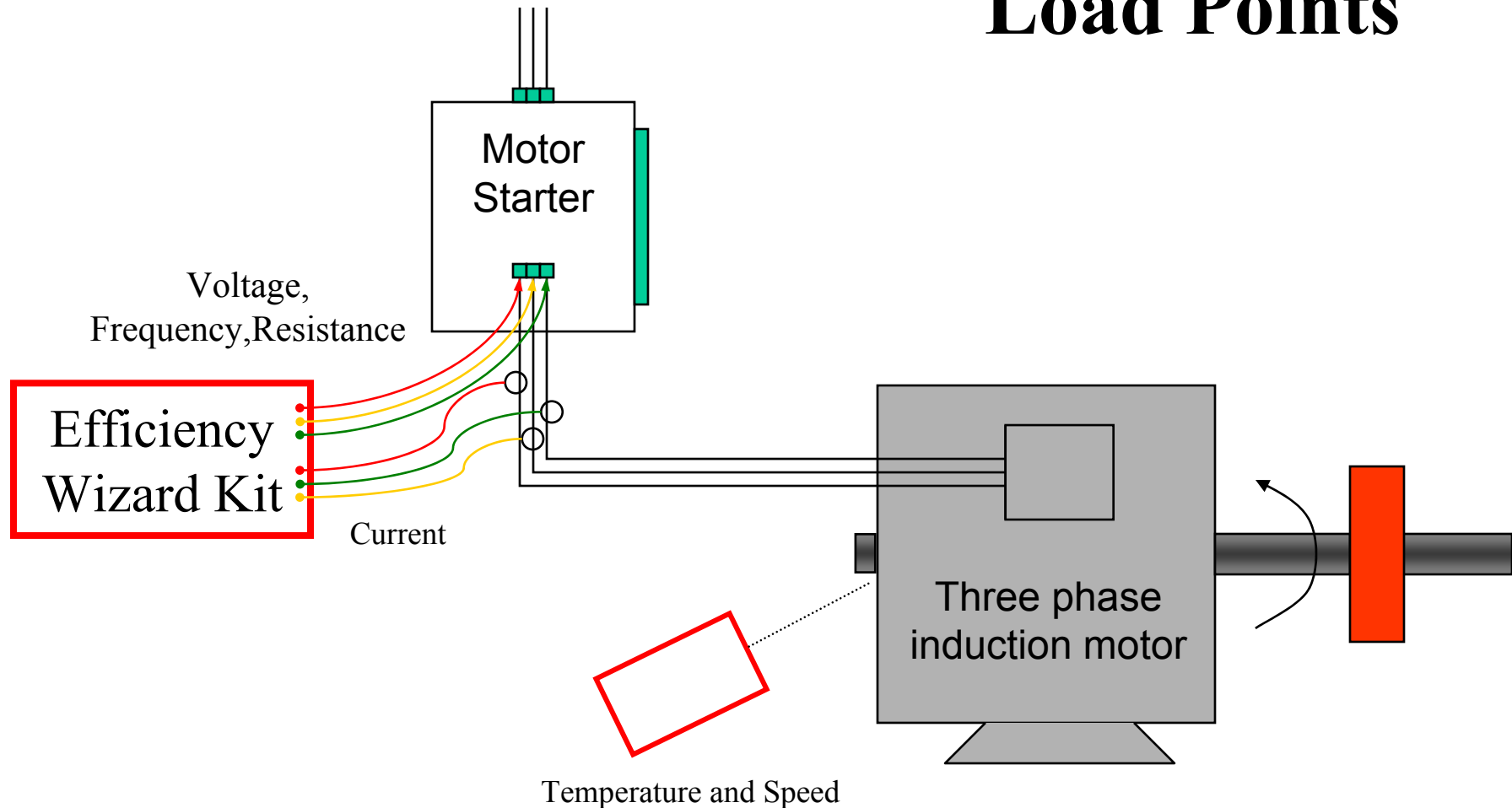
- Energy cost is growing at a high rate
- Plants can save a substantial amount of money by replacing existing inefficient motors with new highly efficient motors
- An accurate method to determine electric motor efficiency is needed to make these decisions
 - Without the need to disconnect the motor from the driven equipment
 - Without the need to make connections at the motor terminal box
 - Include all motor losses
 - Provide both motor efficiency and output load information

Electric Motor Efficiency Wizard

- Portable metering
 - Speed
 - Temperature
 - Resistance
 - Power
 - Voltage
 - Current
 - Frequency
- Laptop computer for data collection
- Proprietary algorithm to calculate motor efficiency



Measurements made at Two Motor Load Points



Test Procedure

- Disconnect motor power at the starter
- Measure line to line resistances at the starter.
- Measure the motor and cable temperature using the Infra Red meter
- Record cable length (starter to motor) and gage

Test Procedure.....

- Connect the Power Monitor and frequency monitor leads at the starter box
 - current, voltage, frequency, input power
- Start data download to the Laptop PC
- Record motor fan diameter and nameplate data
- Start the motor and bring it to normal load condition.
- Measure motor speed and surface temperature at a normal running load and at a second load point.
- Enter data into the Laptop PC

Motor Input Data Sheet

Motor Data	REL S.O.	Frame	HP	Type	Hertz	RPM	
	xxxxxxx		75		60	1185	
	Volts	Amps	Duty	AMB C/INSUL.	S.F.	Nema Design	
	460	91	CONT			B	
	Code Letter	Enclosure	E/S	Rotor	Test S.O. Date	Test Date	
	G	TENV			2/27/02	2/27/02	
Item	RPM	Input Power KW	N. of Poles	Frequency	V L12	V L13	
Test Point 1 "High Load"	1186.7	60.51	6	60.002	466.833	466.833	
Test Point 2 "Low Load"	1193.2	32.976	6	59.995	469.1	469.1	
Item	V L23	I1	I2	I3	Stator Temperature	Cable Temp	F&W watts
Test Point 1 "High Load"	466.833	88.012	88.012	88.012	60	39	250
Test Point 2 "Low Load"	469.1	56.299	56.299	56.299	56	39	250
Stator Resistance & Temperature**	R12 total	R13 total	R23 total	Stator Temperature in C	Cable Temp		
Resistance	0.16	0.16	0.17	51	24		
** Measure the resistance of the stator and record the temperature at the time of measurement.		Motor HP	SLL % of Output				
		1 - 125					
		126 - 500					
SLL % Factor at Rated Power	1.8	501 - 2499					
Performance Curves Rated Voltage	460		Cable Gauge	Cable Length in Feet	Cables /phase		
Performance Curves Rated Freq.	60		1	213.5	1		
Design Factor	1.0325						
Hours Per Week	168						
KW hour cost in dollars	0.05						
Motor Application	#3 Boiler Fan						
XEX Motor Efficiency	95						

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Results Provided

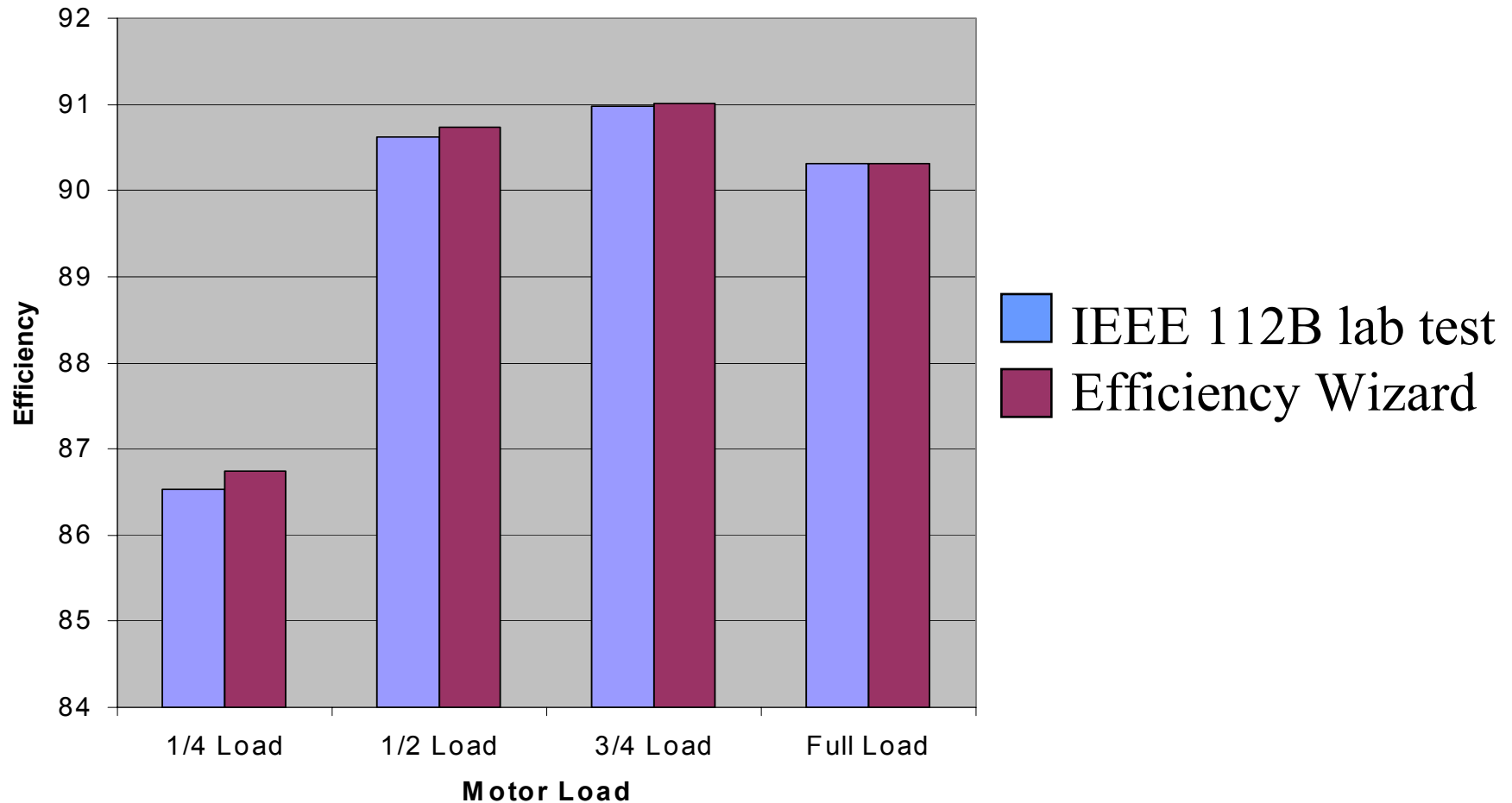
- Motor output torque and horsepower at the two load points
- Motor efficiency at the two load points
 - Includes I^2R , core, friction and windage, and stray load loss
- Motor equivalent circuit parameters
- Performance curves for the motor
 - Power and torque vs speed
 - Efficiency, power factor and current vs load
- Energy savings (in kilowatt hours and \$) if this motor is replaced with an energy efficient motor
 - Given energy cost, hours of operation per week

Output Data Sheet

Motor Data	REL S.O.	Frame	HP	Type	Hertz	RPM
	xxxxxxx	0	75	0	60	1185
	Volts	Amps	Duty	AMB C/INSUL.	S.F.	Nema Design
	460	91	CONT	0	0	B
	Code Letter	Enclosure	E/S	Rotor	Test S.O. Da	Test Date
	G	TENV	0	0	37314	37314
Item	Output HP	Input Current	Speed	Output Torque ft.lb	Power factor	Efficiency
Test Point 1 Hig	72.66	88.0	1186.7	321.6	0.85	90.6
Test Point 2 Lo	38.75	56.3	1193.2	170.5	0.72	88.4
Motor Parameters	Phase Resistance R1&cable	Stator Inductance L1	Core Resistance Rc	Magnetizing Inductance Lm	Rotor Inductance L2	Rotor Resistance R2
	0.057	0.00060	77.471	0.0189	0.00082	0.03767
Output Power HP	Input Current	Power factor	Efficiency	Speed RPM	Output Torque ft.lb.	
5.5	37.2	0.242	57.5	1199.0	24.2	
24.8	46.1	0.595	84.8	1195.6	109.1	
43.4	60.2	0.756	89.2	1192.3	191.0	
60.9	76.4	0.825	90.4	1188.9	269.2	
77.5	93.4	0.857	90.6	1185.5	343.3	
85.4	101.9	0.866	90.6	1183.8	378.7	
92.9	110.4	0.872	90.4	1182.1	412.9	
EXX Motor Efficiency	95					
\$ Savings Per Year	1223					
Annual KWH Saving	24468					

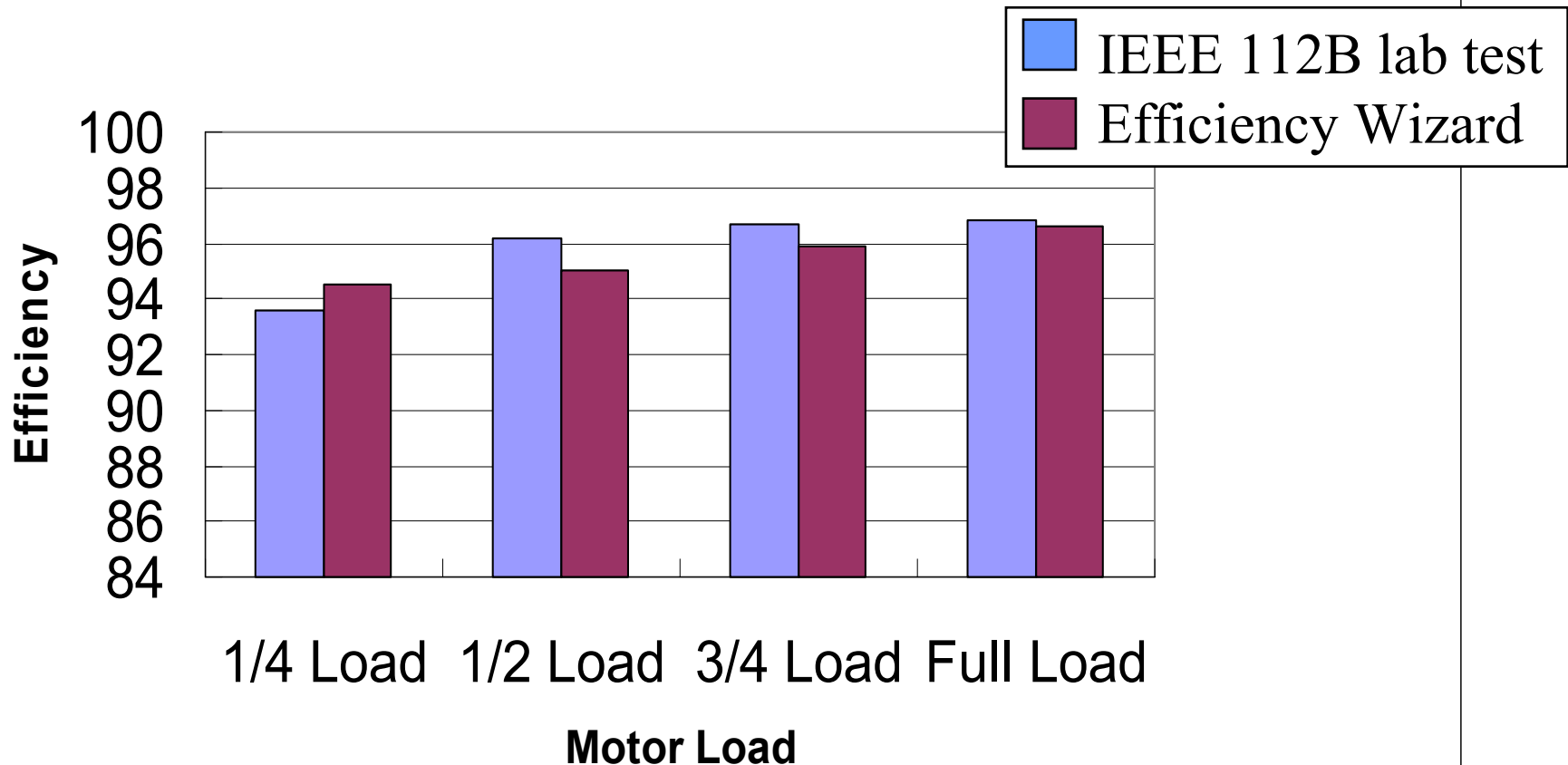
Efficiency Calculation Accuracy

10 HP Motor

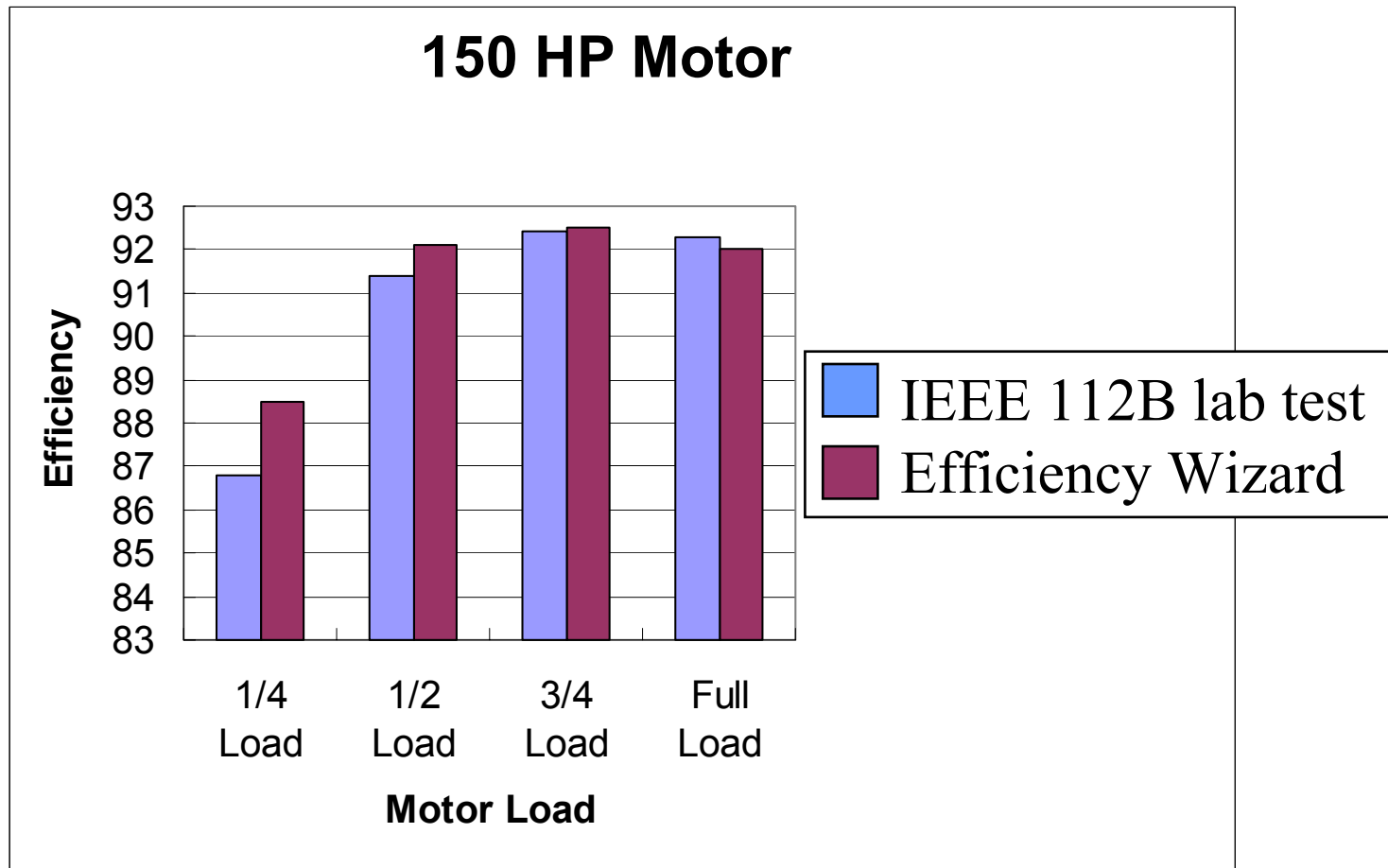


Efficiency Calculation Accuracy

600 HP Motor



Efficiency Calculation Accuracy



Motor Efficiency Versus Output Power

2/27/02

Mitsubishi

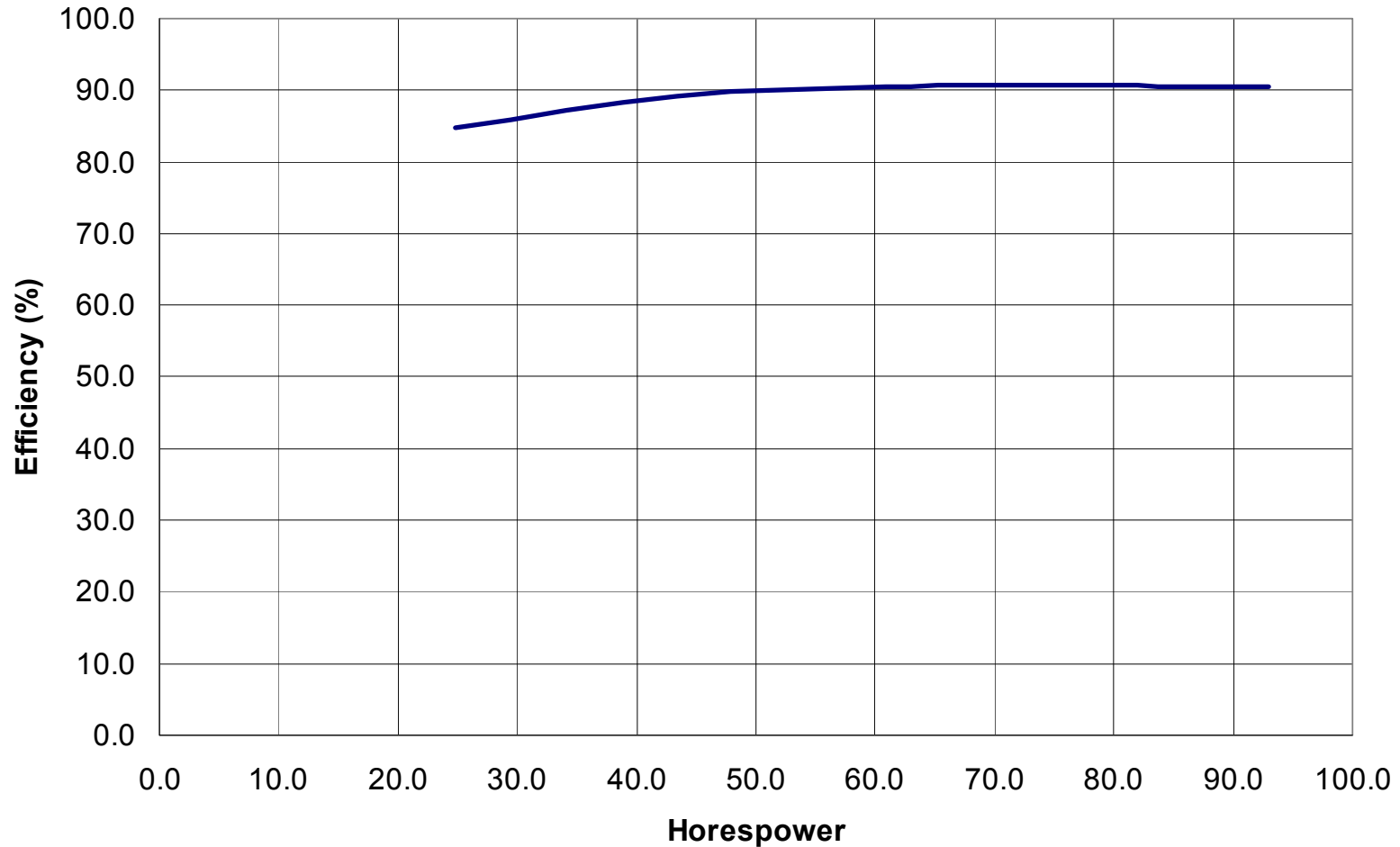
Efficiency

#3 Boiler Fan

REL

xxxxxxx

75 HP



Input Current Versus Output Power

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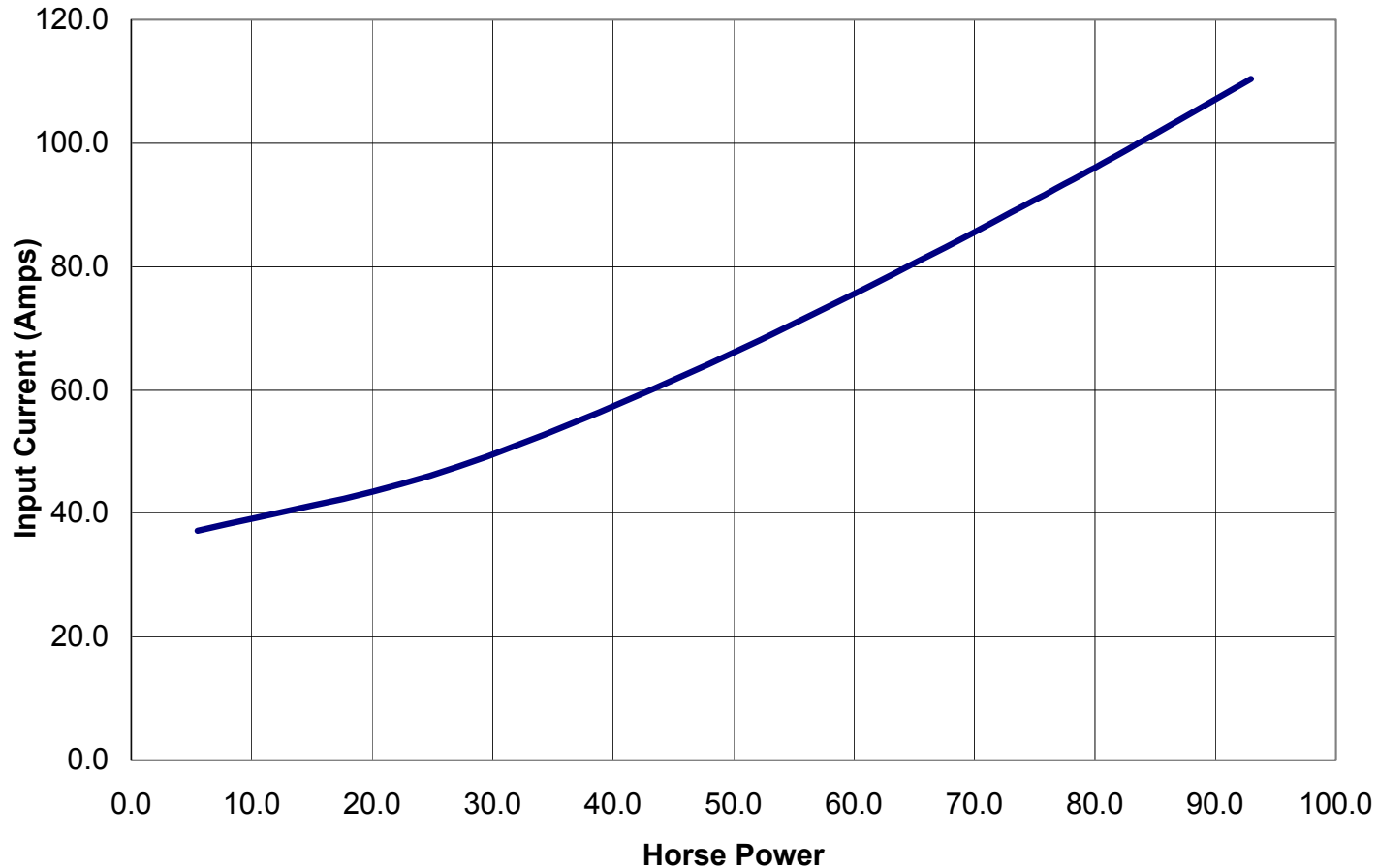
Mitsubishi

Input Current

#3 Boiler Fan

REL S.O. xxxxxxxx

75 HP



Power Factor vs Output Power

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Mitsubishi

Power factor

#3 Boiler Fan

REL S.O. xxxxxxxx

75 HP



Speed vs Output Power

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Speed RPM

#3 Boiler Fan

REL S.O. xxxxxxxx

75 HP



Motor Torque vs Speed

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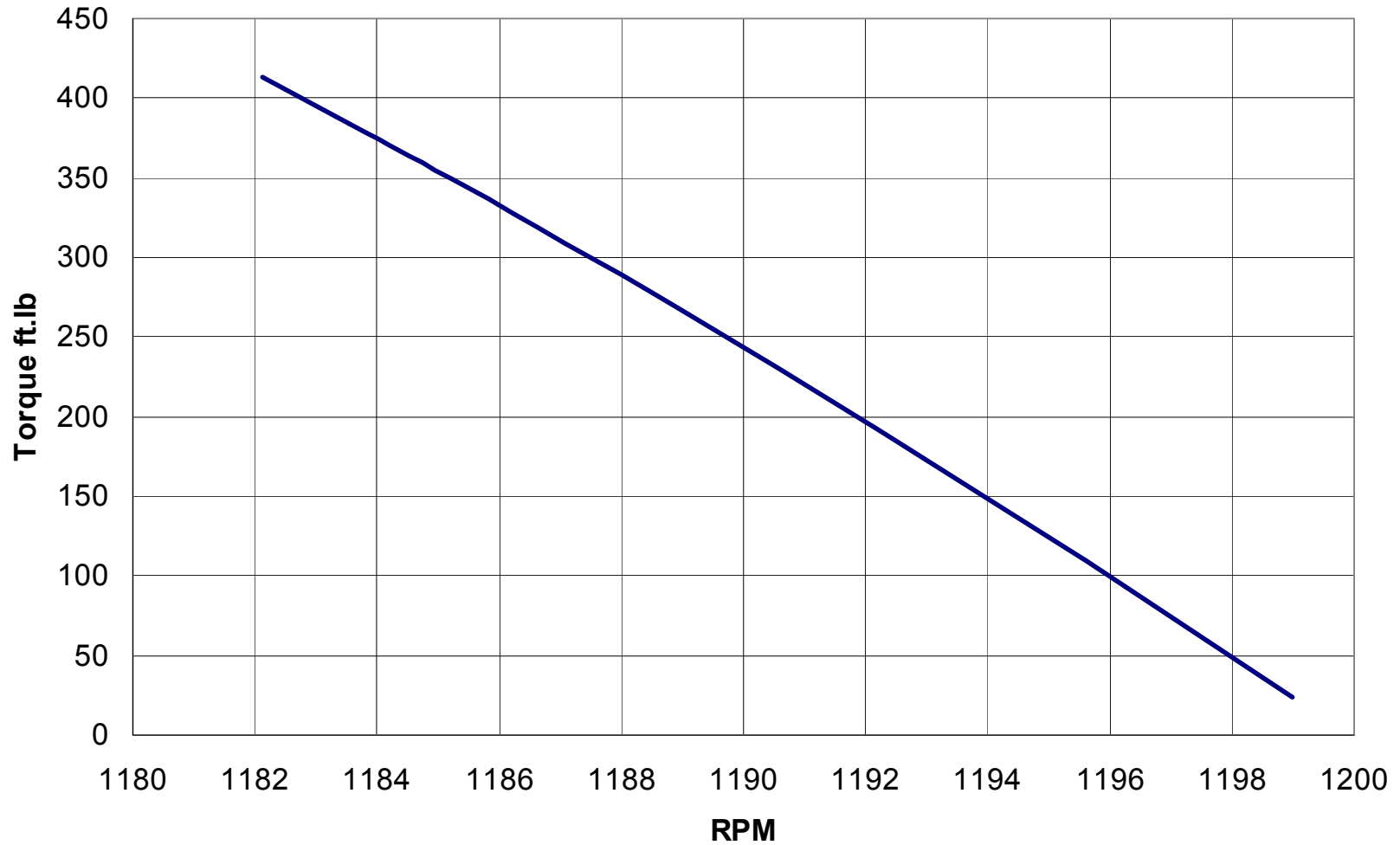
Mitsubishi

Output Torque ft.lb.

#3 Boiler Fan

REL S.O. xxxxxxxx

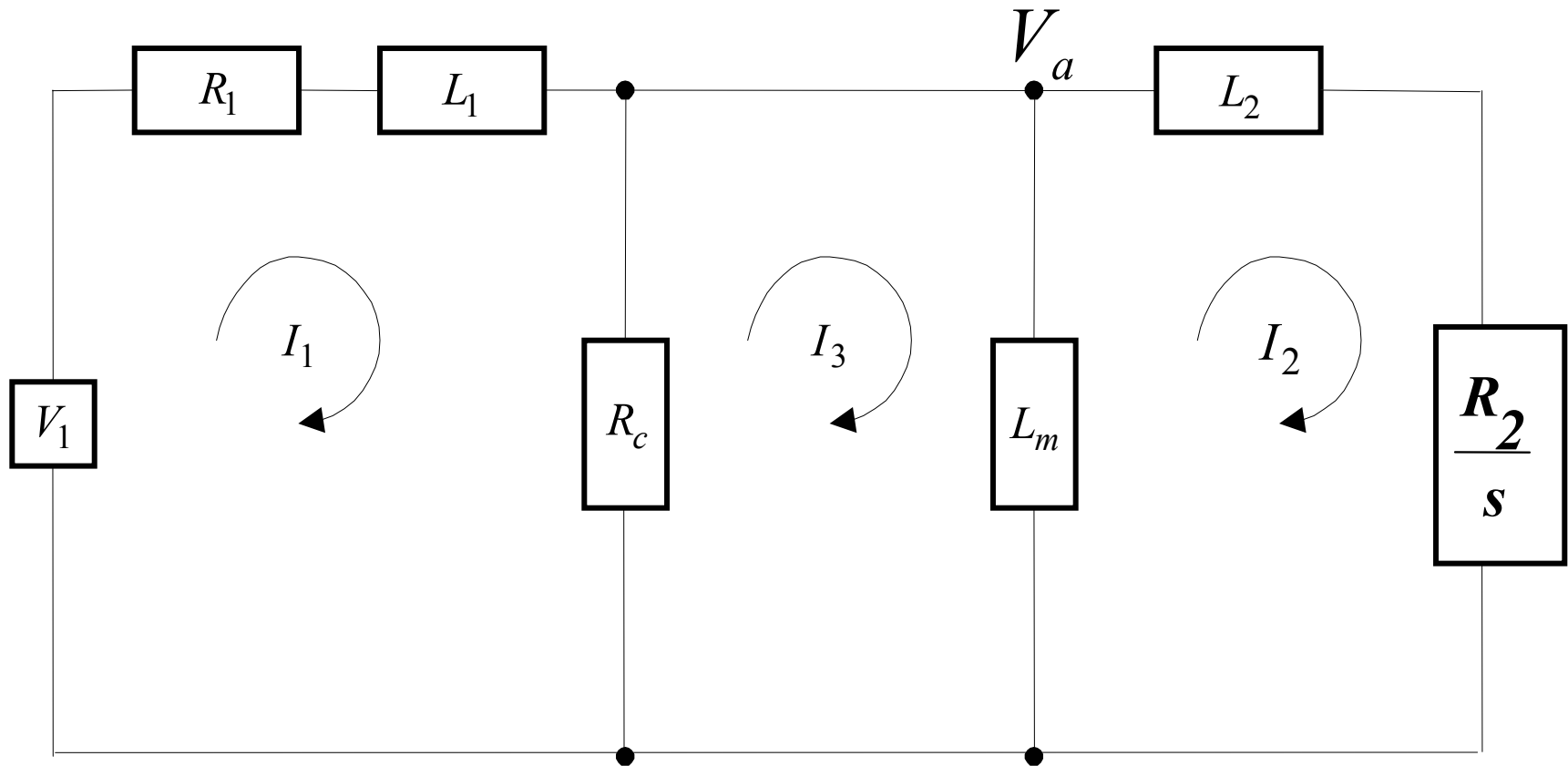
75 HP



How Does it Work

- Input data at the two load points is used to calculate the induction motor equivalent circuit parameters
 - Core loss, stator I^2R loss and rotor I^2R loss are obtained by solving for equivalent circuit losses
- Stray load loss is estimated from IEEE standard formula
- Friction and windage loss is determined from an electric motor database
 - fan diameter and speed as inputs

Induction Motor Equivalent Circuit



How Does it Work

- Performance curves are calculated using the equivalent circuit model
 - efficiency, power, torque, power factor and current vs speed and/or load

Features of the Efficiency Wizard

- All electrical measurements can be made at the motor starter
 - Lead length compensation is included in the software calculations
- No need to mechanically disconnect the motor from the load
 - Two separate load points are required
- Definite purpose portable field kit with high accuracy metering

Features of the Efficiency Wizard

- All motor losses are determined
- Can be used on all induction motors
- High accuracy test results
- Motor performance curves provided
- Automatic calculation of potential energy and \$ savings

Potential Uses

- Provide information for:
 - Decisions to immediately replace a motor with a more efficient one
 - Data base of in-service motor performance
 - Can be used for future motor replacement decisions
 - Can detect under loading or over loading
 - Prioritize present or future motor replacements
- Provides data for fact based decisions on motor replacement
 - Energy savings drop to the bottom line

Example Results

- 250 HP motor
 - Existing motor efficiency = 92.4 %
 - Energy efficient motor efficiency = 96.2%
 - Annual energy cost savings with motor replacement = \$1417
- The present value of the savings over 20 years will be \$15,256.

Conclusions

- An accurate field tool for determining induction motor efficiency has been developed
 - Portable hardware kit
 - Proprietary software
- The new tool can be used on-site without the need to disconnect the motor from the driven equipment
 - Two load points
 - Electrical connections at the motor starter

Conclusions

- Accuracy is to within 1% of laboratory test comparisons
 - 10 hp thru 600 hp
- Motor performance, energy and \$ cost savings are calculated from in-field test data
- Energy saving opportunities can now be readily identified

Thank You